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PROGRAM MANAGEMENT COURSE INDIVIDUAL STUDY PROGRAM

THE IMPACT OF MATERIALS SHORTAGES ON WEAPONS ACQUISITION PROGRAMS:

PAST PROBLEMS AND FUTURE PROJECTIONS

Study Project Report
PMC 76-2

Charles H. Robison
Lt. Col. USAF

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STUDY TITLE: THE IMPACT OF MATERIALS SHORTAGES ON WEAPONS ACQUISITION PROGRAMS: PAST PROBLEMS AND FUTURE PROJECTIONS

STUDY PROJECT GOALS: To understand the implications of materials shortages on weapons acquisition programs and to examine the factors which have a bearing on materials shortages.

STUDY REPORT ABSTRACT:

This study looks at some recent examples where materials shortages have had an adverse impact on weapons acquisition programs in terms of cost escalation and schedule slips. It seeks to derive from these experiences the factors that have contributed to these materials shortages. The study then develops the framework for a materials shortages risk assessment. Of the factors identified, the disruption of the supply of raw materials is chosen for a more detailed examination and the scenarios of cartels, mineral exhaustion, and international competition are discussed.

Cartels to restrict supply of non-fuel minerals were found to be unlikely, except in the possible instance of chromium. Total resource exhaustion through the remainder of the century is also unlikely. ~~However,~~ depletion of the economically recoverable ores, accelerated in part by increased world industrialization and hence competition, will cause rapidly rising prices in all of the basic metals.

The recommendations are designed to address both the near-term ~~, as well as the~~ and long-term aspects of the problem. In the near-term, form a DoD-level action group to collect, correlate, and disseminate information related to materials shortages. In the intermediate time frame, seek legislation to set up a mechanism for "economic stockpiling" of selected critical materials that might be subjected to supply disruption for political or economic reasons (cartels). The longer term ~~and hopefully more permanent,~~ solution is to accelerate the development of a few well-focused materials substitution programs - in particular the use of advanced composites for aircraft.

The results of implementing these recommendations would be to assure the amelioration of the effects of any subsequent materials shortages, ~~such~~ as ~~were experienced~~ in 1973-1974.

SUBJECT DESCRIPTORS: MATERIAL SHORTAGES, WEAPON SYSTEMS, MATERIALS

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THE IMPACT OF MATERIALS SHORTAGES ON WEAPONS ACQUISITION PROGRAMS: PAST PROBLEMS AND FUTURE PROJECTIONS

Study Project Report

Individual Study Program

Defense Systems Management College

Program Management Course

Class 76-2

by

Charles H. Robison
Lt. Col. USAF

November 1976

Study Project Advisor
Dr. Don Hurta

EXECUTIVE SUMMARY

The principle goal of this study is to determine the effect material shortage has on the acquisition of weapon systems. It seeks to delineate some of the factors that bear on these shortages and select one factor in particular - the shortages of raw materials - for a more detailed investigation.

The report looks at related problems that surfaced during the most recent period of shortages (1973-1974), examines the probability of occurrence of certain scenarios that could cause a repeat of the 1974 price escalation and non-availability, and recommends some remedial actions to address both the near-term and long-term projected problems. It also offers a framework for assessing the risks of schedule slips and cost overruns caused by materials shortages.

We find that resource exhaustion, a'la The Club of Rome scenario, will not be a factor for most materials in the near-term, i.e., before the year 2000. However, the depletion of higher grade ores, coupled with increasing cost and concern for the environment, health, and safety will create steady upward pressures on the price of most raw materials.

We also find that, for the present, cartels similar to the OPEC oil cartel, are not likely to be very effective. However, economic and political situations have a habit of changing rapidly and what was once a long shot suddenly becomes very likely. At the present chromium is the mineral whose supply to the United States is most likely to be disrupted by factors unrelated to simple supply and demand.

Far more likely is a supply disruption or a step-function increase in prices, brought about by fierce international competition from other

industrialized nations whose economies are booming in synchronization with the United States.

The recommendations are three-fold:

1. To inaugurate on action group to act as a focal point within DoD for the correlation and dissemination of materials - availability information, both historical and predictive.

2. To increase the funding in well-focused, materials - substitution research and development programs. In particular, accelerate the development and use of advanced composites in aircraft.

3. To seek legislative action to create an "economic stockpile" to act as a hedge against supply disruption for a few selected materials. In the category of non-fuel minerals, only chromium would be recommended for economic stockpiling under the present conditions.

ACKNOWLEDGEMENTS

I am especially indebted to Mr. Edward J. Dyckman of the Defense Industrial Resources Support Office, Defense Supply Agency, who kept me supplied with reports, articles, minutes of meetings and points of contact in other agencies. He also spent the better part of two days answering my questions and talking to me about the causes and effects of the materials shortages problems as he saw them. I could not have completed this report in the time allotted had it not been for Mr. Dyckman's able assistance.

The views expressed in this report are those of the author alone and do not necessarily reflect those of Mr. Dyckman.

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SECTION I

INTRODUCTION AND PURPOSE

A recent article in Aviation Week and Space Technology[1] reported on a cost growth in the F-15 program of almost $1B. This was brought on by a step function increase in the prices for metals and metal products in 1974 caused by materials shortages. This, in turn, forced a deferral of program buys planned for that year in order to remain within appropriations. Inclusion of these in later years is a major contributor to the cost growth. The F-15 is just one of an increasing number of weapon acquisition programs to be adversely affected by shortages of materials.

The overall purpose of this study is to understand the implications materials shortages have for weapon system acquisition programs and to examine the factors which have a bearing on these shortages. Although there are several factors, such as loss of plant capacity, industrial profit optimization, government policies and regulations, etc., this paper will focus on only one factor - that of shortages caused by supply disruption of raw materials.

The goal is to "scope" the problem, present some likely scenarios, and discuss some possible remedial actions.

SECTION II

IMPACT ON WEAPON SYSTEM ACQUISITION PROGRAMS

Materials shortages are playing havoc with weapon systems acquisition programs in terms of increased costs and schedule slippages; and in some cases, the materials are not available at any price, necessitating substitutions which lead to redesign and requalification.

A recent survey conducted by the Aerospace Industries Association of America[2] shows that leadtimes for basic materials increased several hundred percent in 1973-74 and that prices also underwent dramatic escalation. See Table 1.

The difficulties encountered in the aerospace industry were also felt in the shipbuilding industry. The increasing leadtimes and costs made chaos out of shipyard production schedules[3]. A further sign of the squeeze experienced by the defense industries is evidenced by the increase in the number of assistance requests processed under the Defense Materials Priority System[4]. In 1974 the numbers of requests processed by DoD to the Department of Commerce tripled.

Recent Examples

Armor Castings. Because of the horrendous loss of tanks in the 1973 mideast war, the U.S. army sought to accelerate the production rate for M-60 tanks. They discovered that the limiting factor was the production rate of small armor castings. This could not be increased without major facility expansions in the foundry industry, costing millions of dollars. In the case of heavy armor castings, the industry did not want to invest in the capability to produce such a unique component and the Army had to

TABLE 1

AVAILABILITY OF MATERIALS, 1972-74

MATERIAL	LEADTIME, APR 72 (Weeks)	LEADTIME, DEC 74 (Weeks)	PERCENT PRICE INCREASE DEC 73-DEC 74
STEEL PLATE	10	50	45
ALUMINUM PLATE	9	32	145
NICKEL ALLOYS	21	77	-
TITANIUM PLATE	13	40	130
COPPER CABLE	25	45	151

Data taken from Reference 2.

foot the bill. The Army felt that the main cause in the inability of the foundry industry to take on the increased effort was the large number of foundry closings that had occurred during the past several years.

Thermal Batteries. Thermal batteries are used for power applications in a large number of the United States tactical missles, such as Sprint, Maverick, Stinger, Dragon, Redeye, Sidewinder, and Lance. In addition, thermal batteries are also used in nuclear fusing, mortars, artillery shells and aircraft ejection seats. The main reason for their widespread use is their high reliability, long shelf life and wide operating temperature range. Presently, Eagle-Picher Industries, Inc. is the only large scale supplier of thermal batteries, manufacturing 200,000 to 300,000 thermal batteries for several of the aforementioned missile programs.

The problem is that essential chemicals, such as zirconium powder and calcium chromate, have become increasingly difficult to obtain and at the present the entire thermal battery manufacturing base rests precariously on one or two suppliers.

For example, the sole source for zirconium powder in the United States is Ventron Corporation which is having difficulties meeting the specification necessary for the thermal batteries; consequently, Eagle-Picher has been unable to keep its entire production line operating. In addition, a French company is tendering an offer to take over Ventron Corporation. At the moment, Ventron is a national resource, and take-over by a foreign company would not be in the national interest.

Before 1972, Foote Mineral Company was also a supplier. A fire in 1972 destroyed its facility and killed an employee. The company declined to resume production because of the inherent danger in the production process and because the zirconium powder sales contributed only a small percentage

to the company profits.

Another ingredient necessary for thermal battery production is calcium chromate. As of June 1974 Allied Chemical ceased production of calcium chromate because of the added capital expenditures necessary to bring the facility in compliance with OSHA standards. Presently only one company, Reeco Chemical, is willing to supply calcium chromate. Reeco Chemical is a one-man operation and if anything untoward should happen, the entire thermal battery industry is in jeopordy.

Re-entry Vehicle Heatshields. Fibrous carbons and graphites are used in a variety of critical defense applications where ability to withstand high temperatures is necessary.

Some of the uses are for heat shields of re-entry vehicles, throat inserts for rocket motors, leading edges for hypersonic flight vehicles, and aircraft brake systems (in particular for the F-15, F-16, and B-1). The fibrous carbons and graphites are formed by pyrolyzing organic fibers at high temperatures in the absence of oxygen. The organic fiber used as the precursor in the pyrolysis process is continuous filament rayon. For example, Minuteman III anticipates the use of almost 1 billion pounds of rayon over its production lifetime and the Trident propulsion and re-entry vehicle programs will use 6.2 million pounds. The F-15, F-16, and B-1 aircraft will require 1.9 million pounds of rayon, with about 3/4 of this material going for the B-1 brake sets.

The American Viscose Corporation - Food Machinery Corporation (FMC) is currently the only manufacturer of continuous filament rayon which is suitable for the production of fibrous carbons and graphites. This supplier has announced his intentions of ceasing production by 1978.

The continuous filament rayon production is driven by the tire-cord market and this has declined six-fold in the past two decades because of other materials being preferred for tire cords. Other reasons for the corporate decision to quit the business are: 1) increased capital expenditures necessary to comply with OSHA/EPA standards, 2) scarcity of suitable pulpwood (the starting material), 3) obsolete production facilities, and 4) the much higher profitability of staple rayon (as opposed to continuous filament rayon).

Luckily, in this case, DoD has barely enough time to react with substitute materials or stockpiling, or some combination of both. Sudden catastrophic occurrences visited on a single critical supplier could easily preclude any remedial actions by DoD. (It should be noted that requalification of any substitute materials will be vastly expensive.)

Rocket Fuel. The Air Force Titan 2 is practically the sole launch vehicle for military satellites and spacecraft. The Titan 2 is fueled with unsymmetrical dimethylhydrazine (UDMH). One of the intermediate compounds in the present process is N-Nitroso amine which is a carcinogen. FMC is the only supplier and has shut down its Baltimore plant upon completion of its recent Air Force contract primarily because of its sensitivity to public reaction and a rather limited market. Basically, commercial suppliers are reluctant to get into the manufacturing of UDMH because of the limited market and because of the necessity of using a non-hazardous, non-polluting production process. In any case, the price is expected to increase from $0.57 per pound to $6.00 per pound.

Contributing Factors

As the foregoing examples show, the causes of the shortages are many and varied. Armor castings were in short supply because of lack of plant

capacity which was caused in-part by shortage of capital. Profit optimization, resulting in the elimination of certain sizes, shapes, and alloys from the product line, is another reason. More stringent and more expensive safety and pollution standards have resulted in corporate decisions to cease production of certain hazardous materials such as zirconium powder or UDMH. When the tire cord market for rayon diminished, DoD's consumption was not large enough to induce industry to maintain production for re-entry heat shields or aircraft brakes. Finally, relative unavailability of raw materials can cause steep escalation in the costs as in the case of the F-15.

The industry has implemented many stop-gap techniques to alleviate the problem such as purchase for the life of the contract, seek specification relaxation so that a more readily available material may be substituted, or exercise the Defense Materials Program priority system.[4] Unfortunately, all of these solutions are only short term and temporary.

A number of very promising longer term solutions have been proposed,[5,6,7] mostly calling for increased activities in the technology base and looking at shortages from a materials substitution standpoint. A recent study by DoD called Profit '76 addresses policies aimed at creating incentives for industrial capital expansion. Although both are interesting and important topics, they are beyond the scope of the present report.

SECTION III

SHORTAGES OF RAW MATERIALS

Background

There can be no doubt that the United States is dependent on foreign sources for the majority of its non-fuel minerals. The U.S. has an insatiable appetite for raw materials, with five percent of the world's population consuming 27 percent of the raw materials. Putting that into absolute figures, 40,000 pounds of new mineral materials are required annually for each U.S. citizen[9]. The Department of the interior estimates the imports of all non-fuel minerals to be \$14B for 1975 with an expected climb to \$20B by 1985 and to \$52B by 2000[10]. Other statistics indicate that at the present rate of consumption (i.e., a zero-growth environment), the cumulative U.S. consumption of iron ore in the next 41 years would equal the total previous consumption throughout our history. For aluminum the figure is only 14 years[11]. A glance at Table 2 and Figures 1 and 2 graphically depict the situation for these and other minerals.

Is this increasing dependency upon foreign imports a cause for national concern? How and why has this occurred? What are the implications for national defense? What, if anything, should DoD do about the situation? To answer these questions, one must realize this nation's position in non-fuel minerals in an intricate interacting amalgam of economics, technology, and politics, both international and domestic. In some circles, the U.S. dependency on foreign suppliers for raw materials is not all bad. In an economic sense, the situation may result in a net gain for all involved. This idea was put forth some 20 years ago by Peter Drucker[12]. However,

TABLE 2

CHANGING IMPORT REQUIREMENTS OF THE UNITED STATES
(NET IMPORTS AS PERCENT OF DOMESTIC USE)

		1950 NET IMPORTS (%)	1960 NET IMPORTS (%)	1970 NET IMPORTS (%)
	IRON ORE	5	25	30
	CHROMIUM	100	94	100
	COBALT	92	75	96
	COLUMBIUM (NIOBIUM)	100	100	100
FERROUS METALS	MANGANESE	77	92	94
	NICKEL	99	88	91
	TUNGSTEN	80	40	-
	ALUMINUM (BAUXITE)	71	77	86
	COPPER	35	9	8
	LEAD	59	59	40
NONFERROUS METALS	MAGNESIUM	0	1	0
	MERCURY	92	36	38
	PLATINUM	91	95	93
	TIN	100	100	100
	TITANIUM	32	30	47
	ZINC	37	54	60

Data taken from Reference 13

FIGURE 1
U.S. CHROMIUM DEMAND AND SUPPLY

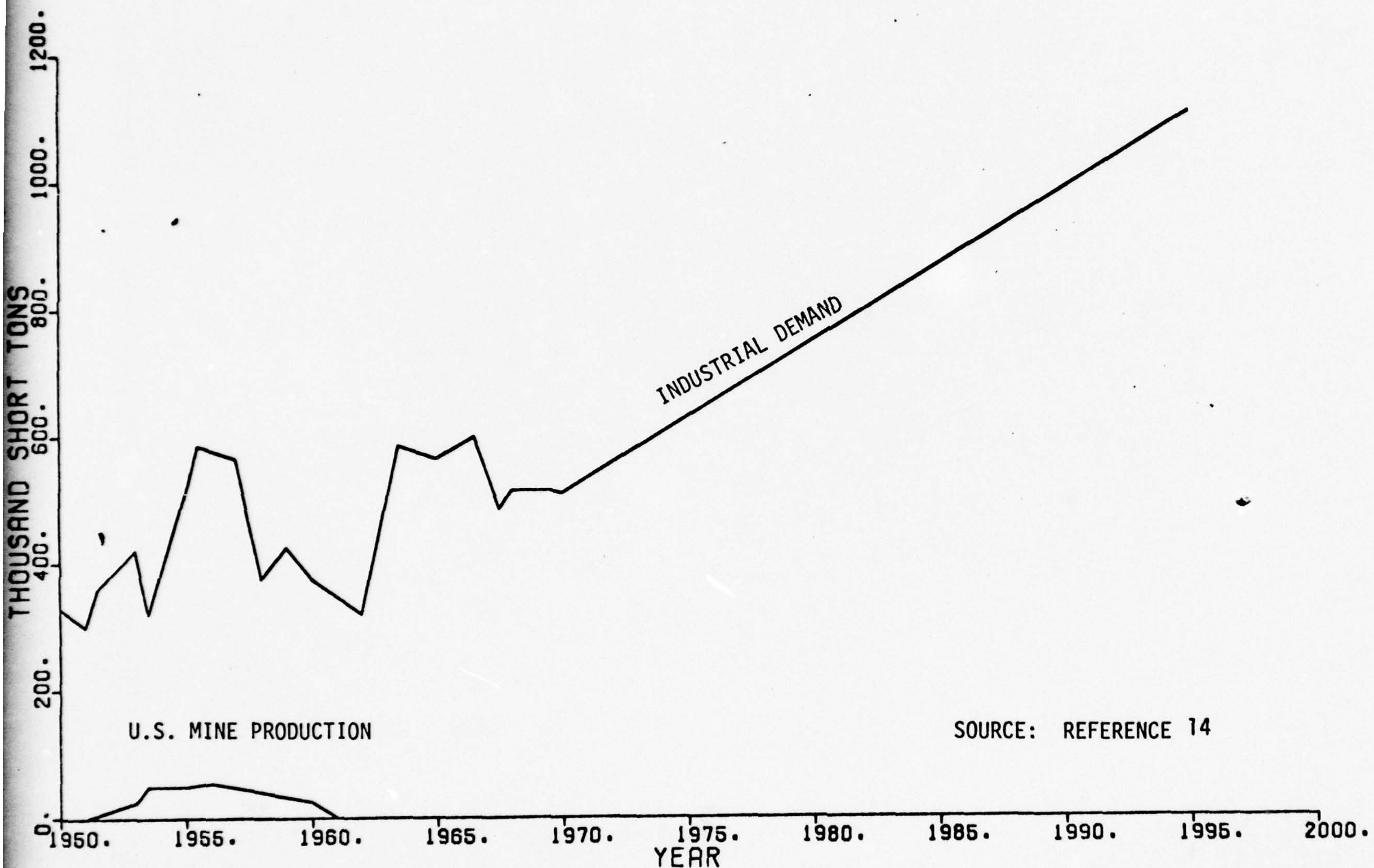
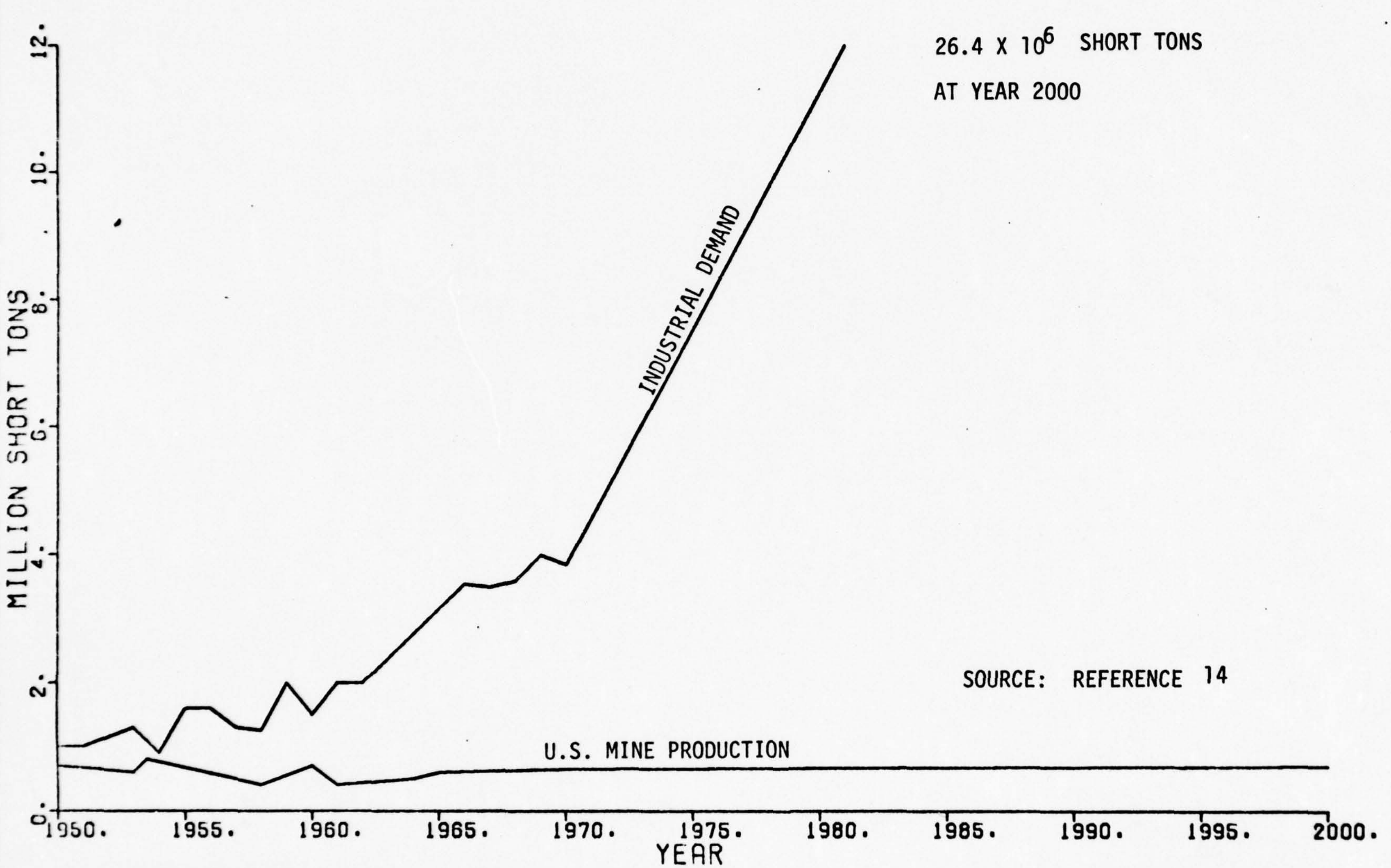


FIGURE 2
U.S. ALUMINUM DEMAND AND SUPPLY



from the strategic military standpoint, the dependency on foreign suppliers takes on extremely negative and potentially grave implications. What seems to be lacking is a cogent national policy that deals with our foreign dependency on a "what if" basis. That is, there seems to be a curious lack of realistic contingency planning.

The set of factors to be considered in contingency planning for war mobilization is different from the set to be considered for peace-time shortages. The war mobilization contingency is met adequately by the strategic materials stockpile program (See Appendix A). The peace-time materials shortages arena is the one that has serious implications for the weapon acquisition business and is the arena with only ad hoc planning.

Possible Scenarios

The massive dependencies on foreign sources of supply for raw materials has strategic and economic implications for the United States. The interruption of supply could be brought on by producer cartels, exhaustion of economically recoverable resources, or fierce international competition. Some of these scenarios are more likely than others and we shall delve into them in more detail.

Cartels. The 1972-74 commodity boom[15] and the OPEC oil boycott brought forth the fears that the industrialized countries would be held for political ransom in any number of primary commodities. A case-by-case analysis shows the likelihood of this to be small. (See, for example, a U.S. Army War College study, reference[16]. It defines a vulnerability index for many of the raw materials.) The requirements for a successful cartel operation, so far are met only by the OPEC countries in the case of oil, are four-fold:

1. Concentration of the particular commodity export in the hands of only a few countries. For example, chromium, titanium, tin and bauxite exports are limited to only a few countries. See Table 3.

2. An inelastic demand for the commodity, i.e., the demand is roughly the same regardless of the price.

3. An inelastic supply for the commodity or its close substitute from sources outside the cartel. Quite often, as the price increases, other sources become economically recoverable or substitutions become economically feasible. For example, the price of oil will reach a point in which recovery from oil shale becomes competitive.

4. Export discipline among the memebers of the cartel. The economic temptation to "cheat" on one's cartel partners varies from member to member and may, at times, become overwhelmingly strong. The members must be financially strong enough to forgo current export earnings when surpluses develop.

An important point should be emphasized however; just because the conditions for cartel formation don't exist now, there is no reason to believe this will always be so. The conditions should be assessed continously.

<u>Exhaustion</u>. The best case for the exhaustion of raw materials and the subsequent collapse of society is made in two Club of Rome Reports[18,19]. Basically these reports show the coupling of resource exhaustion with the increase in pollution and postulate the only hope is for a state of zero growth. Table 4 is from the first Club of Rome Report[18] and shows the effect of present day exponential growth on resource availability. Other writers[20,21] think the long term future is bright provided an inexhaustible

TABLE 3

WORLDWIDE PRODUCTION AND UNITED STATES DEMAND FOR SELECTED MATERIALS

MATERIAL	PERCENT OF WORLD PRODUCTION BY EXPORTERS LISTED	PERCENT OF U.S. DEMAND SUPPLIED BY EXPORTERS LISTED	MAJOR EXPORTERS
BAUXITE	51	69	AUSTRALIA JAMAICA SURINAM
TIN	57	83	MALAYSIA BOLIVIA THAILAND
CHROMIUM	62	50	USSR SOUTH AFRICA RHODESIA
TITANIUM (rutile)	65	44	AUSTRALIA CANADA NORWAY
PETROLEUM	14.6	35	CANADA SAUDI ARABIA NIGERIA VENEZUELA

Data taken from Reference 17.

TABLE 4

RESOURCE DEPLETION

RESOURCE	YEARS TO DEPLETE (CURRENT USE RATE)	YEARS TO DEPLETE (CURRENT GROWTH RATE)
ALUMINUM	96	27
CHROMIUM	420	91
COAL	2300	107
COBALT	110	56
COPPER	32	17
GOLD	7	5
IRON	236	89
NATURAL GAS	34	18
NICKEL	150	49
PETROLEUM	27	16
SILVER	12	9
TUNGSTEN	36	24

Data taken from Reference 18, based on known global reserves.

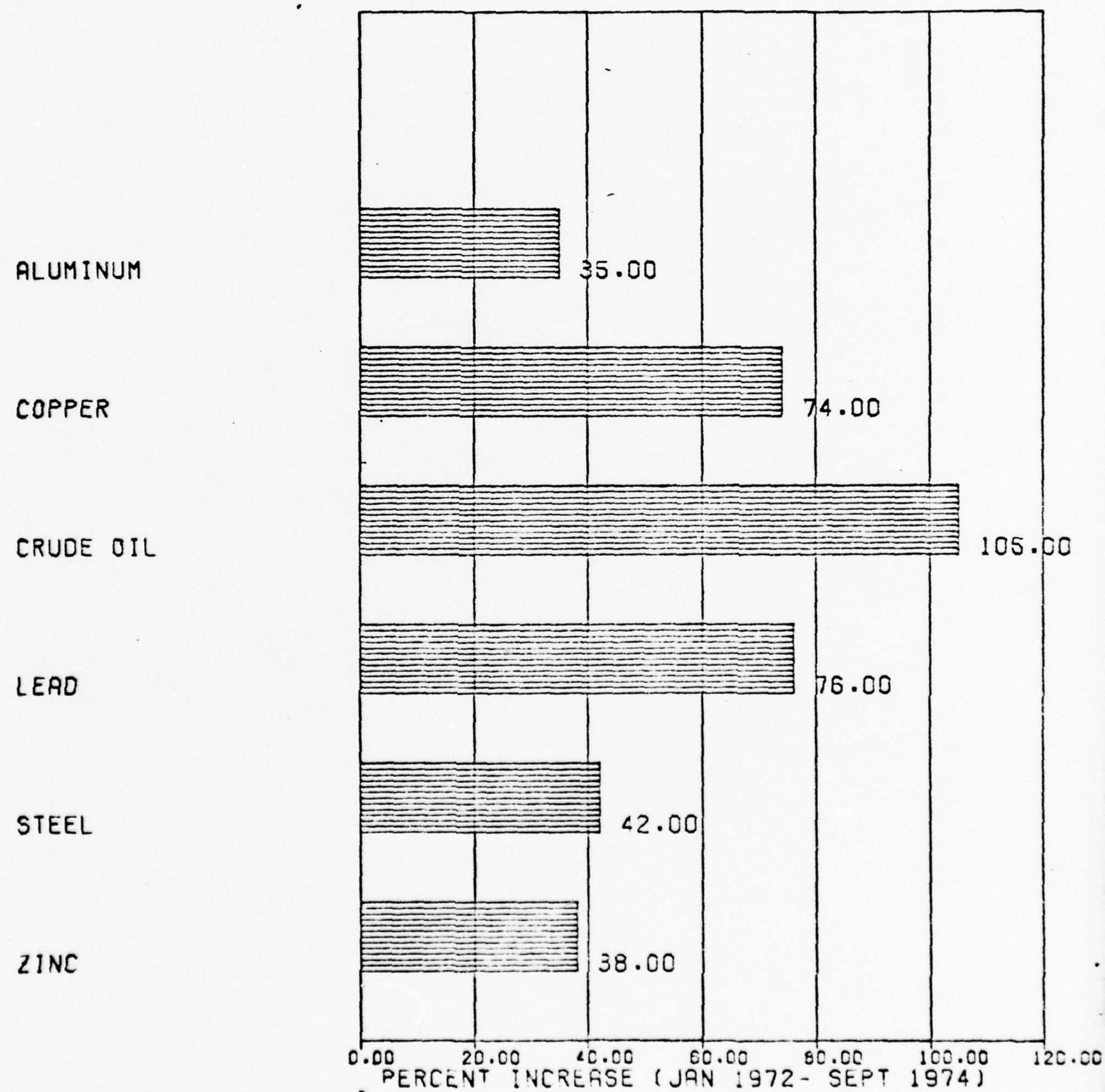
supply of energy exists to process lower grade ores. The production of so much energy, even if possible, calls into account other potential dangers such as pollution and climatic changes[22].

International Competition. A scenario that is much more likely and one that is certainly more insidious is the increase in costs brought on by the competition for raw materials. This competition comes about because of increasing industrialization throughout the world. In fact, the statistic that the U.S. has 5 percent of the population consuming 27 percent of the raw materials has changed downward in the past 2 decades. In 1956, the U.S. had 10 percent of the population consuming 50 percent of the raw materials[12].

Because of the interdependence of the economies of the industrialized world brought on by more liberal trade rules, more covertible currencies and the free flow of investment capital across national boundaries, the booms and slowdowns coincide. For example, the upswing in the U.S. economy in 1972 and 1973 was accompanied by booms in Europe and Japan. This synchronous expansion of the industrial nations led to an all-out scramble for raw materials. This, in turn, led to unprecedented price increases as shown in Figure 3. World industrialization, and hence raw materials consumption, is growing at a faster rate than is U.S. raw materials consumption. This is graphically displayed in Figure 4.

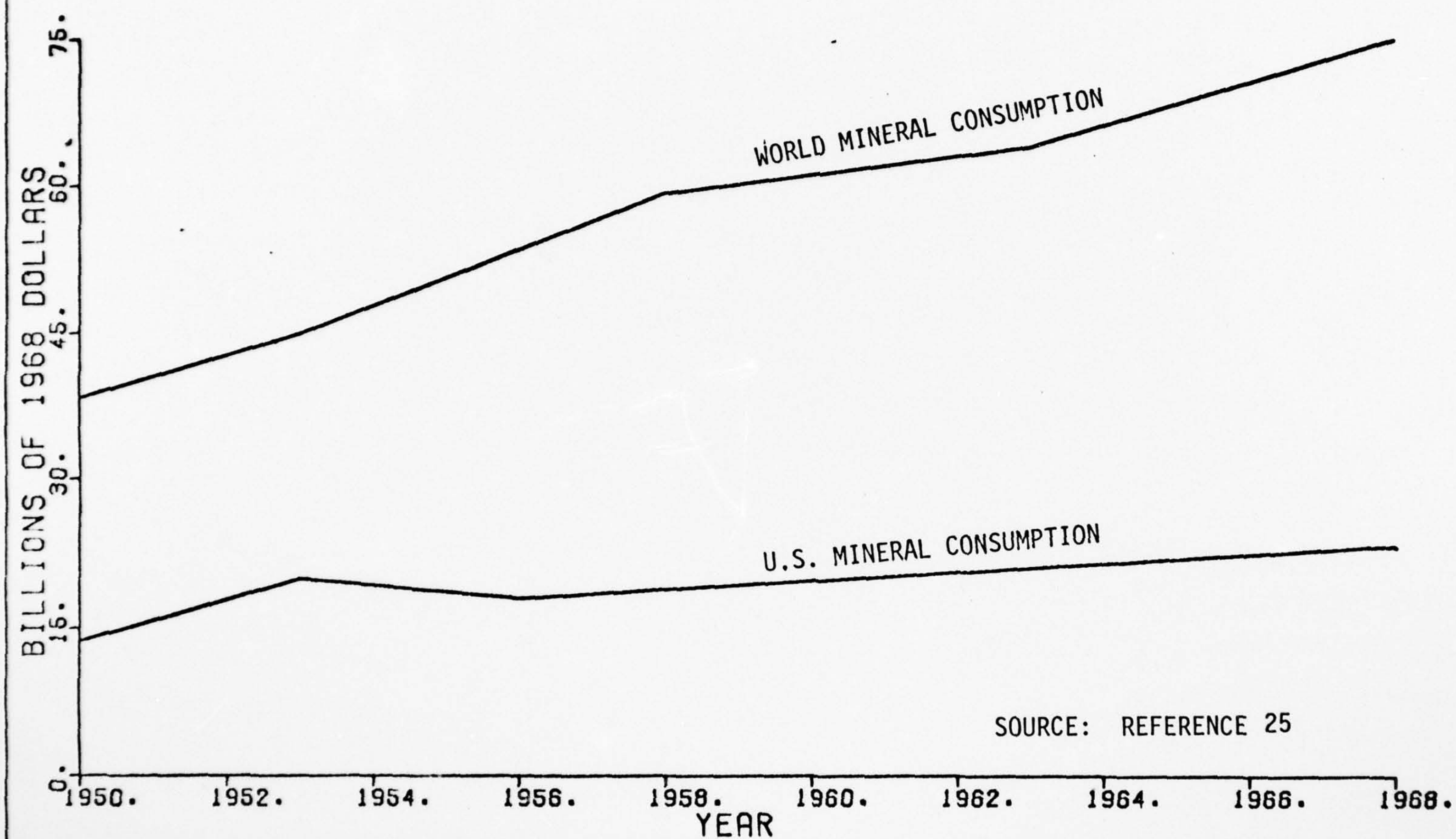
Japan is a special case. It is an industrial giant in spite of being an international resource pauper. For example, it imports 100 percent of its bauxite, chronium, nickel, and tungsten and 90 percent of its copper, iron ore, manganese, and tin. Nor is Japan self sufficient in food. Japan's foreign policy reflects this economic necessity[23], and their

FIGURE 3
SURGE IN UNITED STATES MATERIALS PRICES 1972- 1974



Source: REFERENCE 24

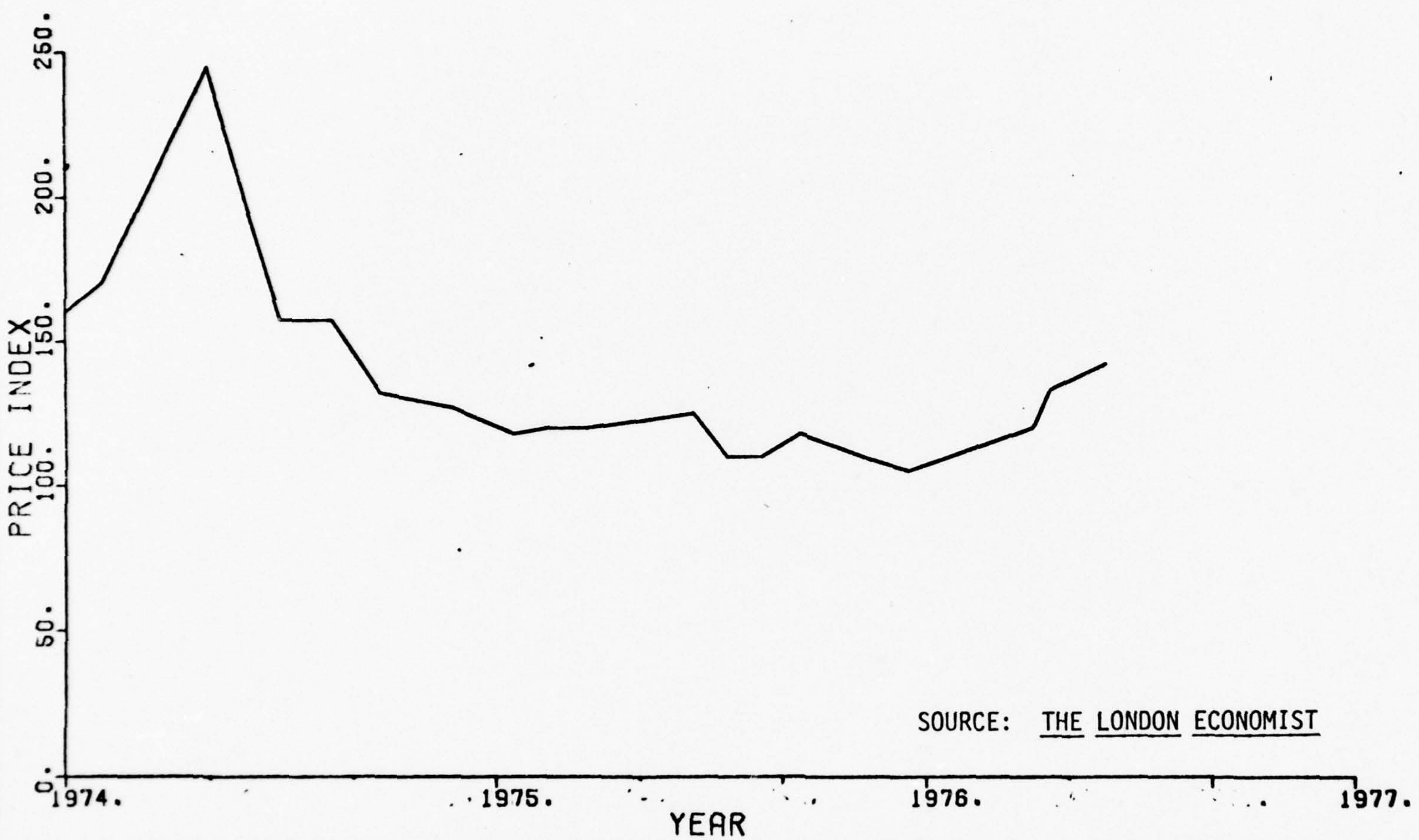
FIGURE 4
WORLD AND U.S. CONSUMPTION OF MINERALS



international dealings with respect to commodities can be expected to be somewhat capricious. Witness, for example, their inclination toward Arab political aims during the recent oil emargo. The point of all this is to call attention to the fact that Japan, for the forseeable future, will be an unrelenting competitor for raw materials.

The common market countries also have been experiencing rapidly increasing raw material consumption and can be counted to bid up the price on scarce commodities. The effects of the present economic recovery can already be seen in the prices on the London Metals Exchange, see Figure 5.

FIGURE 5
METALS PRICE INDEX
1970 = 100



SECTION IV

POSSIBLE REMEDIAL ACTIONS

As is most often the case, there is no simple solution, no single pressure point, no short-term panacea that will insure program stability in the event of shortages. However, there are some actions that can and should be taken at every level. At the program manager level, it is possible to implement a survival strategy in the form of a better framework for assessment to reduce the effects of unknowns. At the service component level a recommended action is to increase funding and emphasis in the technology-base on materials substitution. A shotgun approach to this increased emphasis should be sedulously avoided; rather, specific, well plotted-programs should be aimed at specific problems should be initiated. At the DoD level, there is need for an action group to act as the focal point for predicting problems, disseminating information, developing options, and coordinating actions. Finally at the national level, some economic stockpiling of selected commodities could be a beneficial hedge. These remedial actions will be discussed in more detail in the following paragraphs.

Framework for Materials Shortage Risk Assessment

The program manager with a program in the conceptual or validation phase is constantly performing risk assessments of one variety or another in an attempt to illuminate the areas of "known unknowns" and to reduce the probabilities of cost overruns and schedule slippages. Another risk assessment that needs to be added to the list is an assessment of the potential for material shortages.

The potential for material shortages generally has very limited

visibility in the program office, primarily because the materials buyers are usually located several tiers deep in the sub-contractor structure of a program. However, the previous examples illustrate the consequences that supply dislocation can have on an unsuspecting program.

The following is a list of questions that should be answered in order to pin-point the areas of potential problems:

1. Do any of the essential materials come from a foreign supplier who exports a substantial portion of the world's supply and who for political or financial reasons might seek to cut off the supply? For example 50 percent of the United States chromium demand is supplied by USSR, South Africa, and Rhodesia.

2. Is the material supplier the only qualified source of supply? What happens if a strike, fire, etc. should befall the company?

3. Is the material likely to be in high demand during times of a synchronous worldwide industrial boom? Aluminum, steel and copper will almost surely fall into this category.

4. Is the component manufactured by an industry with limited ability to expand its production capacity? Recall, for example, the foundry industry" difficulty with the armor castings.

5. Is the process for producing the material hazardous or does it create by-products that cause pollution problems? Note, for example, the OSHA standards for 15 chemical carcinogens listed in Appendix C.

6. Is the DoD a customer for a material that has a much broader consumer market? This is usually a good situation in that DoD gets a price break because of the larger civilian market. However, should that market fail, the price and availability may be called into question.

Materials Substitution: The Special Case of Aluminum

Although the Technological possibilities for materials substitution are virtually limitless, the time required to affect the change is usually very long, sometimes as long as 20 years. Because of this fact, we can't wait til disaster strikes to initiate materials substitution R&D programs.

Another aspect of the planning should be to define programs from a functional substitution view point rather than from a one-for-one replacement viewpoint. That is, the substitute material does not necessarily have to have identical properties, so long as its use performs the same function. For example, the use of fiber optics rather than copper wire to carry signals. In this case the fiber optics materials are not even electrically conductive.

One area of particular concern is the substitution of advanced composites for aluminum for aircraft structural members.

The long-term trend for the price of Aluminum is almost surely up. This projection is made in terms of constant dollars (i.e., inflation discounted), even though the price of aluminum over the past two decades (until 1973) has been remarkably stable. Since most of the airplanes in production or full scale development are made from aluminum, this bodes for a substantial future cost growth in all of them. The increase in the cost of materials has already adversely affected the F-15[1].

This pressure for escalating the price of aluminum is expected to continue at least through the turn of the century and is brought on by the impending confluence of a number of events. For example, the dependence on foreign sources, the increasing cost of energy, the increasing costs of environmental considerations, the increasing consumption rates, and the increasing cost of capital needed for plant expansion should all combine to drive up the price.

Even though aluminum is the third most abundant element (behind oxygen and silicon) on the earth, making up 8.1 percent by weight of the earth's crust, the richest ores (bauxite) are limited. Some worst case projections (See Table 4) predict exhaustion of the economically recoverable ores shortly after the year 2000. Exhaustion or not, the relative scarity is sure to drive the price of raw materials through the ceiling.

Sixty nine percent of the U.S. demand for bauxite is supplied by three countries, Australia, Jamaica and Surinam. Since all of these countries are nominally our friends and in need of the revenue brought by the sale of minerals, one would not have reason to believe the supply would be cut off capriciously. However, the long sea route necessary to the transport of the majority of the bauxite leaves open the opportunity for mischief.

The aluminum industry is one of the most energy-intensive industries in the United States, consuming approximately 4% of the nation's electricity. A significant portion of the power is derived from hydroelectric sources; consequently, the production (and hence the price) is related to rainfall and snowfall. For example, a drought in 1973 retarded aluminum production in the pacific northwest which accounts for 32 percent of the United States production capacity.

Although the U.S. has substantial reserves of aluminum-bearing ores other than bauxite, the costs of using these lower grade ores is enormous. The problems associated with their processing are due to the increased volume of material that must be handled. Larger energy inputs are required for mining, transportation, crushing and grinding. The increased energy required for processing lower grade ores is indicated by the fact that

U.S. mineral production has risen 50 percent in the last 50 years; whereas, the energy consumption for processing has increased 600 percent in only 25 years.[27]

Environmental considerations are also a potential issue. Kaolin clay and anorthosite are generally surface materials. These are most economically available through strip mining which is prohibited in some areas. Producing alumina from clays creates a waste disposal problem. Six tons of kaolin clays are required to produce 1 ton of aluminium. The comparable figure for bauxite is 4 tons. In addition, between 1 and 1.5 tons of red mud waste is produced per ton of alumina. The present technology deals with this by impounding such mud in large diked lakes ranging in size up to 2000 acres. Suffice it to say that land-use conflicts could be an important consideration in developing domestic aluminum resources.

Another aspect of the stricter environmental standards that affects the defense department more than the civilian sector is in the manufacturing of high-purity, fracture-tough alloys. In order to meet environmental regulations on air emissions and still remain competitive, the captured emissions are recycled to the process. This has the affect of increasing the impurity level of the aluminum, especially in the iron content. Low levels of iron and silicon are necessary for the production of alloys with high levels of fracture toughness. Fracture toughness is a <u>sine-qua-non</u> for military aircraft. There is probably not enough of this alloy available to sustain a high production rate of military aircraft. In any event, the special alloy is expected to cost much more.

As pointed out earlier in this paper (Figure 4), the world demand for minerals is rising at a faster rate than the U.S. demand. During the

period from 1964 to 1973, for the specific case of aluminum,[28] the world production of bauxite increased by 131 percent. At the same time the United States consumption decreased from 40 percent of the world production to 37 percent. The increased demand for dwindling resources can have but one effect on the prices, i.e., send them skyward, as happened in 1973-74.

What is the answer? How can we avoid the all-but-inevitable price escalations in military aircraft caused by the increase in the price of aluminum? One answer is substitution, specifically the use of advanced composites in aircraft construction. Composites would not be affected by the factors that are acting to drive up the price of aluminum. The materials are 100 percent domestically available, the energy requirement is less by 54 percent, and the environmental considerations are minimal. What is needed is more R&D money to accelerate the technology so as to be able to step into the breach with confidence when the price of aluminum goes so high as to price are out of the market. Both the Air Force and Navy presently use advanced composites on aircraft. For example, the F-14 has the empannage, the over wing fairing, and wheel-well door made from advanced composites. The F-15 uses them on the speed brake and empannage structure. This particular substitution trend is underway already; however, it needs to be greatly accelerated.

DoD Materials Shortages Action Group

The body that comes the closest to fulfilling the role of a "Shortages Action Group" as defined in the opening paragraph of this section is an ad hoc committee sponsored by the ODDR&E and I&L in the Defense Department, called the DoD Materials Shortages Steering Committee. Its objectives are to 1) explore the establishment of a materials data base, 2) plan a tri-service program aimed at the technology base on materials substitution, and

3) maintain a liaison with other governmental agencies and industry on the subject of materials availability.

What is needed is a permanent group. It doesn't have to be a newly chartered organization, but rather an existing related OSD organization with an expanded mission and slightly augmented manpower. Its success will depend on how well it can coordinate the diverse groups involved and how well it can correlate the plethora of information on materials into some kind of early warning system.

A very large amount of data exists in the government on the subject of materials supply and demand. It is spread over practically every department in the executive branch of the government as well as special offices reporting to the congress. See Appendix B. All of the departments use and analyze different aspects of the data for their own purposes, but to date there have been only sputtering attempts to correlate the available data into some kind of early warning system.

A five month effort by Battelle, called the Strategic Materials Management Information Program (SMMIP), was a step in the right direction but was discontinued for lack of funds. Its objective was to "provide a continuing resource of authoritative information and data on the adequacy of current and future supplies of selected materials determined to be essential to the military program.

One interesting observation during this five month effort was that the sub-tier contractors were the ones who had most need for the information. The government and the large prime contractors were buyers of components and partially-completed systems rather than of materials. This had the effect of obscuring the potential material shortage probiem until it was too

late to do much about it.

Using a less sophisticated, but no less valuable, method, the Navy has developed a nomograph for predicting lead times for essential materials a year in advance.[30]

Another effort that shows some promise is the Department of Commerce's early warning system for prediction of commodity supply dislocations. It is aimed at supply dislocations in the economy as a whole and not tailored specifically to DoD applications. Nevertheless it has the potential to pinpoint future problems when it becomes fully operational.

A materials information and analysis system for the purpose of identifying potential supply problems used within a coordinated framework would be well worth the effort. Its objectives would be to anticipate both short and long-term supply bottlenecks and potential large price increases.

With this information available far enough in advance, the program manager in the DoD as well as in the prime contractor's plant could attempt to take some action that would ameliorate the adverse effects. For example, they could rearrange the purchasing or production schedules or initiate searches for alternate materials or processes to avoid the materials in short supply.

Economic Stockpiling

Another possible strategy for dealing with raw materials shortages would be to institute an economic stockpile (as distinct from the strategic and critical materials stockpile described in Appendix A). The purpose of an economic stockpile would be to affect the price or distribution of raw materials to the benefit of the United States. It would be used to deter shortage problems or ameliorate their effect if they do occur. One could wonder, for example, how an effective oil stockpile might have offset the

effects of the OPEC oil embargo.

The Office of Technology has recently published a very thorough assessment of economic stockpiling[27] using a cost/benefit trade off approach. The report considered stockpiling for anti-cartel purposes, for supply disruption caused by political unrest, for stabilizing prices, for conservation of scarce resources, and for flywheel purposes. Although ostensibly for national security reasons the critical materials stockpile has in fact been used for economic purposes both in the price stabilization mode and the flywheel mode (See Appendix A). The size of the stockpile required to achieve price stabilization would be enormous and attempts on an international scale have met with only mixed success. For example, the International Tin Council has managed to keep a floor under the price of tin, but has exhausted its stockpile - without achieveing price stabilization on the up side.

Economic stockpiling as a hedge against unpredictable supply disruptions (i.e., cartels, political unrest, sea blockade, acts-of-God etc.) should be seriously considered in the case of chroniumn and platinum. These materials have a fairly high vulnerability index[16] and cannot be displaced easily by substitutes. See Table 4 for a summary of their vulnerability characteristics.

A sudden supply disruption of either chromium or platinum, both of which the U.S. imports in significant amounts, would cause an impact on the U.S. economy. Also note from Table 4 that one of the major suppliers is not noted for friendship to the U.S. and the other two are presently experiencing political unrest.

Short term (1 year) price elasticity is to be interpreted that a doubling of the price of chromium (platinum) would bring about only a 20%

TABLE 4. VULNERABILITY CHARACTERISTICS OF CHROMIUM AND PLATINUM

Material	Percent Reduction in GNP for 20% shortfall	Percent DoD Use[a].	Major Exporters[b]	Percent of U.S. Demand Supplied by Exporters listed[b]	Short Term Price Elasticity[c]	Pct of U.S. demand imported[b]
Chromium	4.2	6.5	USSR South Africa Rodesia	50	-0.2	91
Platinum	5.3	3.6	USSR South Africa	68	-0.1	80

a. Reference 26
b. Reference 17
c. Reference 31

(10%) decrease in the demand.

Chromium is very high on the list for materials to be included in an economic stockpile, and perhaps is really the only one. Platinum within a few years will be thoroughly incorporated into the capital infrastructure of the U.S. in the automobile catalytic converter. That is, eventually the U.S. will have stored in its junk automobiles a significant fraction of the world's platinum.

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

Summary of Conclusions

Materials shortages have, in recent years, become a problem for weapon acquisition programs. These shortages have caused dramatic price escalations and unanticipated schedule slips, bringing to the consciousness the realization that this is another of the many potential ambushes along the long road from concept to deployment.

There is ample evidence to suggest these shortages are likely to continue and under certain circumstances, even worsen. The shortages are more likely to be from the international competition for the dwindling, economically recoverable resources brought on by increased world-wide industrialization, than by any cartel action similar to that successfully employed by the OPEC nations in the case of oil.

One step up from the raw material shortage problem is the chemical or processed-material problem. There is an increasing disinclination of industry to use capital to expand into areas characterized by small profit margins, low volume markets, or the use of hazardous or polluting processes.

The conditions for another commodity price escalation, a'la 1973-74, are again present and another scramble for scarce resources is to be expected before the end of the decade. We are not a lot better off now in terms of contingency plans or predictive capability than we were 4 years ago and the prospects for the long range are no better.

In any case, the Program Manager should be aware of the strong possibilities that exist for materials shortages to throw the program out

of balance with unexpected schedule slips and escalating costs.

Recommendations

1. Increase R&D funding in selected areas of materials substitution. At the present time, there appears to be an imperative need for accelerating the development of advanced composites for aircraft as a substitute for aluminum.

2. Form a special actions group whose responsibility it would be to correlate all the materials - related information available in the federal government. The group would act as a focal point for the collection and dissemination of information bearing on potential shortages of materials of vital importance to the Department of Defense. Finally, it should in conjunction with other government agencies such as the commerce Department, develop a predictive capability.

3. Encourage legislation to set up the mechanism for economic stockpiling of selected materials to be stockpiled on a very limited basis. At the present time, the situation seems to warrant only the economic stockpiling of Chromium. The action group recommended in the previous paragraph would have the responsibility to assess continually the political and economic parameters relating to potential materials shortages and make recommendations for additional materials to be stockpiled for economic purposes and materials to be deleted from economic stockpiling.

APPENDIX A

STOCKPILING HISTORY IN THE U.S.

The first stockpile resulted from the Strategic Materials Act of 1939 when Congress appropriated $70M to buy rubber, tin, quartz and chromite as a hedge against worsening conditions is Europe. In 1946 Congress passed the Strategic and Critical Materials Stockpile Act. Section 1 of the Act stated:

> "To supply the industrial, military and Naval needs of the country for common defense ..... It is the policy of Congress and the purpose and interest of this Act to provide for the acquisition and retention of stocks of these materials and to encourage the conservation and development of sources of these material without the United States, and thereby decrease and prevent whenever possible a dangerous and costly dependence of the United States upon foreign nations for suppliers of these materials in times of national emergency".

Section 5 goes on to say that the President can authorize the use of materials from the stockpile when:

> ".....such release is required for the purposes of the common defense, or in time of war, or during a national emergency with respect to common defense.......".

The Defense Production Act of 1950, passed at the onset of the Korean war, and the Agriculture Trade and Development and Assistance Act of 1954 completed basic stockpile legislation.

These three acts give rise to three official stockpiles: The National Stockpile, the Supplemental Stockpile, and the Defense Production Act (DPA) Inventory. The Supplemental stockpile is created by bartering Agricultural products and is considered to be part of the strategic and critical materials stockpile even through it is legislatively distinct. The DPA inventory was to act as a "flywheel" for industry as it expanded to meet the Korean war production needs.

The stockpile objectives (quantity to be stockpiled) are determine by the difference between the estimated supply and the estimated requirements under assumptions such as length of wartime mobilization, degree of civilian austerity, economies of the U.S. and foreign countries, etc.

Various policy guidance through the years has perturbed the objectives. The original criteria was for a 5 year, non-nuclear mobilization contingency. In 1958 the Joint Chiefs of Staff reduced it to 3 years. In 1972 it was reduced to 1 year on the assumption that this country could engage in limited war with a limited stockpile because the economy was large and diverse enough to provide sufficient material for the contingencies we faced.

The resulting reduction brought the value of the stockpile objectives from \$4800M to \$700M. Interestingly enough, the run-up in commodity prices in 1972-73 increased the market value of the objectives to \$1200M. Just recently[32] (Aug 76) the planning factor was again increased to 3 years.

Agency Responsibilities

1. National Security Council - Establish broad defense policies, including those applicable to materials.

2. Office of Emergency Preparedness - Coordinate mobilization activities, to include programs to assure an adequate supply of material in time of emergency.

3. Department of the Interior - Recommend means for insuring adequate supplies of materials to meet mobilization requirements.

4. Department of Agriculture - Responsible for agricultural commodities and activities in connection with bartering agricultural surpluses.

5. Department of Commerce - Develops requirement estimates for industrial and civilian segments of the economy.

6. Department of Defense - Develops estimates of military requirements.

7. General Services Administration - Purchases, stores, and sells materials for the stockpile in accordance with established legislation.

Past Economic Benefits Of The Stockpile

Even though the stockpile releases are justified on the grounds of national defense, many of them have had salutory economic side effects. For example, a 10 year program of disposal of aluminum surplus from the stockpile ended in June 74. Over this entire period, industrial purchases from the stockpile accounted for 3.8% of the total consumption.[27] Over the period 1973-74, when there was a surge in consumer demand, the stockpile supplied 12% of the market.

In another instance, the national stockpile bought the output from domestic titanium sponge producers, since it was vital to the defense mobilization base. This move was necessary to keep them in business because the pressures of foreign competition and large user inventory accumulations had caused the near-term market for titanium sponge to become singularly unattractive.

On several occasions, both copper and nickel have been "sold" to the U.S. Mint from the stockpile. In fact, nickel dispersals from the stockpile (ending in 1972) to both industry and the Mint netted the government a $78M profit.

APPENDIX B

SOURCES OF MATERIALS - AVAILABILITY INFORMATION

There are a large number of departments, agencies and ad hoc commissions and committees in the federal government chartered to collect, analyze, and disseminate information on materials and commodities. For the most part, these groups operate independently and their functions and products usually are known to only a relative few. A list of these committees and agencies follows:

DoD materials Shortages Steering Committee - This committe, sponsored by ODDR&E and I&L in the Department of Defense, has been in existence since December 1974. Its objectives are to 1) explore the establishment of a data base to provide detailed information for the DoD on predicted material shortages, 2) plan a comprehensive tri-service program in R&D for materials substitution, and 3) maintain a liaison with other governmental agencies as well as industry.

The National Commission on Supplies and Shortages - This commission was chartered by the National Commission on Supplies and Shortages Act of 1974 and was to 1) determine the possibility of long-or short-term shortages, 2) determine the adverse impact of these shortages on consumers, 3) assess alternative action necessary to increase the availability of supplies, 4) assess the impact of governmental policies and practices and, 5) recommend necessary legislative and administrative actions which facilitate the availability of essential resources.

Environmental Protection Agency, Industrial Analysis Branch - The mission of this branch is to assess the impact of EPA regulations on

industry.

Federal Preparedness Agency - This agency is concerned with the Defense Production Act of 1950 and specifically determines priorities and allocation (Title 1), stock pile objectives (Title II), and attempts to improve industrial preparedness (Title III).

U.S. Geological Survey (Department of Interior) - USGS provides information about the location and distribution of U.S. domestic material resources.

Bureau of Mines (Department of Interior) - The Bureau of Mines collects, analyzes, and disseminates information on economically recoverable minerals and condusts R&D programs in metallurgy and mining technology.

Defense Supply Agency - DSA has an industrial resources group that tracks leadtime and price information.

Department of Commerce - The Bureau of Domestic Commerce within the Department of Commerce has 2 sub units which have significant materials analysis capability. They are the Office of Business Research and Analysis (OBRA) and the Office of Industrial Mobilization. OBRA has some 140 industry analysts and specialists, who maintain up-to-date coverage on 325 manufacturing and 222 service industries. They analyze and predict supply problems within the government in a broad range of commodities, from raw materials to finished products. The Office of Industrial Mobilization develops mobilization requirements estimates for the industrial and civilian segments of the economy for input into the determination of stockpile objectives. It also administers the Defense Priorities System and the Defense Materials System.

In addition to the ongoing activities, the Department of Commerce plans to inititate on Early Warning System within OBRA. Its objective is

to predict supply aberrations. This is an admirable, if ambitious, undertaking; however, it presently is progressing very slowly.

Department of State - The State Department has a Strategic Materials Division within its Bureau of Economic and Business Affairs.

Treasury - The Treasury has an Office of Raw Materials and Ocean Policy.

Committee on Materials (COMAT) - The Federal Council for Science and Technology established COMAT in early 1975. Its charter was to identify key points of emphasis for federal materials R&D, identify interactions between materials, energy, and environmental issues, and foster the advance of materials science and engineering as related to national needs and goals.

Office of Technology Assessment (OTA) - OTA is a relatively new agency of the United States Congress, coming into existance with the Technology Assessment Act of October 1972. Its goal is to keep congressional policy makers appraised of the opportunities and alternatives provided by technology. Materials is one of 10 areas OTA maintains surveillance on. They have just recently published an assessment of economic stockpiling.[27]

APPENDIX C

OSHA STANDARDS

OSHA Standard	Chemical or Material	Limitation
1910.1003	4-Nitrobiphenyl	0.1% by weight or volume
1910.1004	alpha-Naphthylamine	1.0% "
1910.1005	4.4'-Methylene bis (2-chloroaniline) (MOCA)	1.0% "
1910.1006	Mehyl Chloromethyl ether	0.1% "
1910.1007	3,3-Dichlorobenzidine (and its salts)	1.0% "
1910.1008	bis-Chloromethyl ether	0.1% "
1910.1009	beta-Naphthylamine	0.1% "
1910.1010	Benzidine	0.1% "
1910.1011	4-Aminodiphenyl	0.1% "
1910.1012	Ethyleneimine	1.0% "
1910.1013	Beta-Propiolactone	1.0% "
1910.1014	2-Acetylaminofluorene	1.0% "
1910.1015	4-Dimethylamino-azobenzene	1.0% "
1910.1016	N-Nitrosodimethylamine	1.0% "
1910.1017	Vinyl Chloride	No Exception

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